RDT&E BUDGET ITEM JUSTIFICATION SHEET (R-2 Exhibit)					DATE February 1999					
APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA1 Basic Research					R-1 ITEM NOMENCLATURE Defense Research Sciences PE 0601101E, R1 #2					
COST *(In Millions)*	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	Cost To Complete	Total Cost
Total Program Element (PE) Cost	66.706	64.429	64.293	68.792	69.837	75.398	78.259	81.118	Continuing	Continuing
Information Sciences CCS-02	16.376	18.627	19.002	19.500	19.700	19.700	20.700	21.700	Continuing	Continuing
Electronic Sciences ES-01	36.192	20.322	23.124	29.339	29.084	34.645	35.506	36.365	Continuing	Continuing
Materials Sciences MS-01	14.138	25.480	22.167	19.953	21.053	21.053	22.053	23.053	Continuing	Continuing

(U) Mission Description:

(U) The Defense Research Sciences Program Element is budgeted in the Basic Research Budget Activity because it provides the technical foundation for long-term improvements through the discovery of new phenomena and the exploration of the potential of such phenomena for national security applications. It supports the scientific study and experimentation that is the basis for more advanced knowledge and understanding in information, electronic and materials sciences.

(U) The Information Sciences project supports basic scientific study and experimentation in information sciences technology areas such as computational models, Quantum Computing, biological computing and human-language systems.

(U) The Electronic Sciences project explores and demonstrates electronic and optoelectronic devices, circuits and processing concepts that will provide: (1) new technical options for meeting the information gathering, transmission and processing required to maintain near-real time knowledge of the enemy and the ability to communicate decisions based on that knowledge to all forces in near-real time; and (2) a substantial increase in performance and cost reduction of military systems providing these capabilities.

(U) The Materials Sciences project is concerned with the development of: high power density/high energy density mobile and portable power sources; processing and design approaches for nanoscale and/or biomolecular materials and interfaces; medical pathogen countermeasures; materials and measurements for molecular-scale electronics; advanced thermoelectric materials for cooling and power generation; and novel propulsion concepts.

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(U) **Program Change Summary:** (*In Millions*)

	FY 1998	FY 1999	FY 2000	FY 2001
Previous President's Budget	68.332	65.102	65.400	70.036
Current Budget	66.706	64.429	64.293	68.792

(U) **Change Summary Explanation:**

FY 1998	Decrease reflects SBIR reprogramming and minor realignment of program priorities.
FY 1999	Decrease reflects reductions associated with Congressional adjustments.
FY 2000/01	Decreases reflect reductions associated with lower projected inflation rates.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA1 Basic Research					R-1 ITEM NOMENCLATURE Defense Research Sciences PE 0601101E, Project CCS-02					
COST *(In Millions)*	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	Cost To Complete	Total Cost
Information Sciences CCS-02	16.376	18.627	19.002	19.500	19.700	19.700	20.700	21.700	Continuing	Continuing

(U) Mission Description:

(U) This project supports scientific study and experimentation that is the basis for more advanced knowledge and understanding in information sciences technology areas related to long-term national security requirements such as computational models and new mechanisms for performing computation and communication involving quantum physics, biological and optical processes. This project is also exploring innovative approaches to the composition of software and novel human computer interface technologies.

(U) In the area of quantum computing, the project will identify and probe new classes of computing technologies, which may offer spectacular performance/cost/size/weight/power improvements beyond the ultimate limitations of today's semiconductor-based computing. Quantum logic, based on subatomic scale physical phenomena, could enable a tremendous leap in computational capacity. However, a number of significant hurdles, including the development of sequencing mechanisms, large scale storage, input/output channels and quantum-enabled approaches to algorithms and error correction must be overcome.

(U) In the area of biological computing, the project will support the scientific study and experimentation that is at the interface of information technology and biological technology, with emphasis on biological software, computation based on biological materials, physical interfaces between electronics and biology, and interactive biology. It will also apply information technology to accelerate the analysis and synthesis of biological processes. The seamless integration of information technology and biological processes will provide the ability to exert computational control over biological and chemical processes.

(U) In the area of optical communication and computing, the project will explore new approaches to transmission based on solitons and identify novel buffering technologies that can be substituted for optical delay lines.

(U) In the areas of software engineering, the project will investigate formal techniques for the construction of safety critical systems.

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(U) In the area of human computer interfaces the project will study information management, interface technologies and their relationship to cognitive processes.

(U) Program Accomplishments and Plans:

(U) FY 1998 Accomplishments:

- Investigated computational models suitable for implementation using Quantum computing techniques. ($ 5.681 Million)
- Developed architecture for low-power configurable computational elements. ($ 1.303 Million)
- Prototyped robust spoken and text language technologies with emphasis on affordable grammars and understanding. ($ 7.479 Million)
- Evaluated quality of service specifications; demonstrated real-time adaptive control and resource management; released version of defense-critical software based on scalable library technology. ($ 1.913 Million)

(U) FY 1999 Plans:

- Demonstrate and validate computing models, with emphasis on: DNA-based logic operations and cell-based computation. ($ 4.410 Million)
- Investigate novel control mechanisms for self-organizing and autonomous systems. ($ 2.779 Million)
- Demonstrate human-computer interaction for crisis planning. ($ 3.690 Million)
- Investigate feedback-driven approaches to information management. ($ 6.241 Million)

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- Validate low-power configurable architecture; develop supporting software; and demonstrate automated mapping of 500K elements. ($ 1.507 Million)

(U) FY 2000 Plans:

- Biological Computing. ($ 5.902 Million)
  - Evaluate alternative approaches to DNA-based computing and identify the most promising research opportunities for enhancement and acceleration.
  - Explore mechanisms for sequencing of DNA-based computations.
  - Investigate novel approaches to real-time biological instrumentation in support of interactive biology.

- Quantum and Optical Computing. ($ 4.000 Million)
  - Develop new algorithms for quantum-enabled computation.
  - Design sequencing and input/output mechanisms for quantum computing.
  - Identify alternative optical buffering technologies.

- Software Engineering and Human Computer Interface. ($ 9.100 Million)
  - Investigate design of domain specific languages for use in safety critical systems.
  - Investigate machine translation and relevance of new results in cognitive science research to spoken language and haptic interfaces.

(U) FY 2001 Plans:

- Biological Computing. ($ 6.900 Million)
  - Prototype demonstration of robot control sequencing of DNA-based computations.
  - Demonstrate real-time multi-sensor imaging of cell processes in support of interactive biology.

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- Quantum and Optical Computing. ($ 4.000 Million)
  - Simulate new algorithms for quantum-enabled computation and evaluate potential speed-up over conventional methods.
  - Prototype demonstration of sequencing and input/output mechanisms enabling quantum computing.
  - Laboratory demonstration of soliton-based packet multiplexing, incorporating optical buffering.

- Software Engineering and Human Computer Interface. ($ 8.600 Million)
  - Develop formal methods to support domain specific languages for use in safety critical systems.
  - Investigate interface technologies to facilitate the tasking and management of autonomous systems.

(U) Other Program Funding Summary Cost:

- Not Applicable.

(U) Schedule Profile:

- Not Applicable.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA1 Basic Research					R-1 ITEM NOMENCLATURE Defense Research Sciences PE 0601101E, Project ES-01					
COST *(In Millions)*	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	Cost To Complete	Total Cost
Electronic Sciences ES-01	36.192	20.322	23.124	29.339	29.084	34.645	35.506	36.365	Continuing	Continuing

(U) Mission Description :

(U) This project seeks to continue the phenomenal progress in microelectronics innovation that has characterized the last decades by exploring and demonstrating electronic and optoelectronic devices, circuits and processing concepts that will: 1) provide new technical options for meeting the information gathering, transmission and processing required to maintain near real-time knowledge of the enemy and the ability to communicate decisions based on that knowledge to all forces in near real-time; and 2) provide new means for achieving substantial increases in performance and cost reduction of military systems providing these capabilities. Research areas include new electronic and optoelectronic device and circuit concepts, operation of devices at higher frequency and lower power, extension of diode laser operation to new wavelength ranges relevant to military missions, development of uncooled and novel infrared detector materials for night vision and other sensor applications, development of innovative optical and electronic technologies for interconnecting modules in high performance systems, research to realize field portable electronics with reduced power requirements and research addressing affordability and reliability. Additionally, electronically controlled microinstruments offer the possibility of nanometer-scale probing, sensing and manipulation for ultra-high density information storage “on-a-chip”, for nanometer-scale patterning, and for molecular level analysis and synthesis. These microinstruments for nanometer-scale mechanical, electrical and fluidic analysis offer new approaches to integration, testing, controlling, manipulating and manufacturing nanometer-scale structures, molecules and devices.

(U) This project is also concerned with coupling university based engineering research centers of excellence with appropriate industry groups to conduct research leading to development of advanced optoelectronic components critical to enhancing the effectiveness of military platforms that enable warfighter capabilities for comprehensive awareness and precision engagement and contribute to the continued advancement of Next Generation Internet capabilities. Topics to be researched include emitters, detectors, modulators and switches operating from infrared to ultra violet wavelengths, and related heterogeneous materials processing and device fabrication technologies for realizing compact, integrated optoelectronic modules.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA1 Basic Research	R-1 ITEM NOMENCLATURE Defense Research Sciences PE 0601101E, Project ES-01

(U) Program Accomplishments and Plans:

(U) FY 1998 Accomplishments:

- Optoelectronics - Demonstrated feasibility of using Gallium Nitride detectors as a UV solar-blind detector for missile threat warning and demonstrated UV/blue lasers operating continuous wave for high-density memory and chemical/biological detection. ($ 9.200 Million)
- Infrared Detector Materials - Determined process for low temperature deposition of thin film uncooled materials. ($ 2.600 Million)
- UltraElectronics - Demonstrated feasibility of combining a resonant tunneling device (RTD) with conventional devices, silicon based quantum metal oxide semiconductor (MOS) technology and simple quantum cellular automatic logic circuits using silicon and silicon germanium structures. ($ 10.000 Million)
- UltraPhotonics - Demonstrated practical means for implementing high speed optical buffer memories and signal address recognition based on coherent, all-optical (photon-echo) technology. Demonstrated the utility of low cost silicon electronic devices doped with optically active elements (such as Erbium) for applications that were the exclusive domain of more expensive compound semiconductor devices or glassy materials. ($ 9.000 Million)
- Low Power Electronics - Completed low-power electronics programs in the areas of circuit architecture and power management techniques. Demonstrated 256 x 256 pixel image sensor with on-chip, 10-bit Analog-Digital Converter. ($ 5.392 Million)

(U) FY 1999 Plans:

- Infrared Detector Materials - Establish feasibility of new uncooled detector structures, including micromachined arrays, thin film ferroelectrics and bolometric materials. ($ 2.861 Million)
- UltraElectronics - Demonstrate programmable matched filter operating at gigahertz speed with substantially less power than silicon complimentary metal oxide semiconductor (Si CMOS), completely integrated molecular beam epitaxy (MBE) growth system that realizes closed-loop control of atomic layer growth and quantum device structures. ($ 4.641 Million)

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- UltraPhotonics - Identify the device properties limiting performance of vertical cavity lasers and demonstrate methods for controlling their output beam quality. ($ 7.378 Million)

- Integrate promising new elements of ultraelectronics, high power electronics, non-volatile memory and Electro-Magnetic Interference (EMI) electronics. Address, evaluate and apply current EMI thrusts in smaller, lighter, more mobile information systems and highest performance components and systems. ($ 2.389 Million)

- Initiate mechanical electronics development resulting in very high efficiency DC-DC converters. ($ 0.954 Million)

- Terahertz Technology - Explore technologies for a region of the electromagnetic spectrum (300Ghz to 10Thz, 1mm to 30 micrometer) that has previously been difficult to access using conventional technologies, in order to exploit opportunities in environmental sensing, upper-atmosphere imagery and covert satellite communications. ($ 2.099 Million)

(U) **FY 2000 Plans:**

- Mechanical Electronics - Demonstrate the properties for mechanical switches that include device speed and current density scale and size, hysteretic behavior for non-volatile memory applications and reduce the threshold switching voltage to below 10V. ($ 1.898 Million)

- Terahertz Technology - Continue to exploit the terahertz region of the electromagnetic spectrum by investigating the best semiconductor approaches to sources and detectors, identifying mission critical operation and investigate the feasibility of integrating these components to form a range of compact subsystems for applications in space based communications, remote sensing, collision avoidance radar and covert communications. ($ 3.416 Million)

- Microinstruments – Research new technology for diagnostic instruments to support, maintain and service the warfighter and military platforms. Investigate new technology concepts that support high volume/low cost wearable and hand-held diagnostic instruments. Microinstruments “on-a-chip” concepts that integrate sensors, electronics, storage, display and actuation are the goals of this research. Microinstruments that include fluid dispensing and fluid sensing and fluid identification are important for "in-the-field" medical, chemical/biological and equipment diagnostics and repair. ($ 9.810 Million)

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- Establish university centers of excellence in optoelectronic engineering research and identify methods for transitioning research results to industry. ($ 8.000 Million)

(U) FY 2001 Plans:

- Terahertz Technology - Demonstrate, for the terahertz spectral region, the best semiconductor quantum-well approaches to sources, demonstrate semiconductor quantum-well detectors and identify system requirements to achieve space communications, upper-atmosphere imagery and close-operations covert communications. ($ 3.800 Million)

- Microinstruments - Demonstrate a patterning microinstrument that writes a pattern of array of 50nm minimum - feature-size (MFS) bits or pixels at a rate of $6cm^2$/sec over an area of $1cm^2$. Demonstrate fluidic patterning of pixels 20nm x 20nm over a 1mm x 1mm area using a microinstrument "on-a-chip". Demonstrate an array of 10,000 probes for imaging 10nm defects, electrical pads or bits on an integrated circuit. Demonstrate non-destructive controlled manipulation of cells. ($ 13.539 Million)

- Demonstrate methods for materials processing for the integration of heterogeneous materials to realize innovative optoelectronic modules for sensing and communicating. ($ 12.000 Million)

(U) Other Program Funding Summary Cost:

- Not Applicable.

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(U) Schedule Profile:

- Not Applicable.

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APPROPRIATION/BUDGET ACTIVITY RDT&E, Defense-wide BA1 Basic Research					R-1 ITEM NOMENCLATURE Defense Research Sciences PE 0601101E, Project MS-01					
COST *(In Millions)*	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	Cost To Complete	Total Cost
Materials Sciences MS-01	14.138	25.480	22.167	19.953	21.053	21.053	22.053	23.053	Continuing	Continuing

(U) Mission Description:

(U) This project is concerned with fundamental research leading to the development of high power density/high energy density mobile and portable power sources, advanced thermoelectric materials for cooling and power generation, processing and design approaches for nanoscale and/or biomolecular materials and interfaces, materials and measurements for molecular-scale electronics, medical pathogen countermeasures and novel methods for reducing drag in future generations of high-speed ships.

(U) Program Accomplishments and Plans:

(U) FY 1998 Accomplishments:

- Electrochemistry. ($ 8.511 Million)
  - Constructed and tested a logistics fueled fuel cell power plant for mobile electric power applications.
  - Began component and system study/demonstration of a direct oxidation fuel cell for replacement of military standard batteries.
  - Explored alternative sources of energy for portable power applications (for example, piezoelectric materials).
  - Developed and demonstrated thermophotovoltaic materials with significantly improved performance.

- Nanoscale/Biomolecular Materials. ($ 1.350 Million)
  - Exploited recent advances in materials design and processing to demonstrate nanostructural control of materials properties with an emphasis on emulating the complex microstructure and scale of biological materials.

- Pathogen Countermeasures. ($ 2.477 Million)
  - Determined one or more mechanisms a stem cell could use to link the detection of a pathogen to the production by the cell of vaccines and/or therapeutics.

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- Thermoelectric Materials. ($ 1.800 Million)
  - Demonstrated materials with a factor of two increase in the thermoelectric figure of merit.

(U) **FY 1999 Plans:**

- Portable Power. ($ 9.391 Million)
  - Optimize catalysts, membranes and separator plates for high energy density solid oxide and direct methanol fuel cells.
  - Brassboard testing of compact, high performance 500W solid oxide fuel cells for portable power applications.
  - Demonstrate novel 500W thermophotovoltaic power sources based on advanced materials.

- Nanoscale/Biomolecular Materials. ($ 6.300 Million)
  - Demonstrate the applicability of nanostructural materials in defense applications such as armor, high strength fibers, coatings or electronics.
  - Explore novel concepts in biomolecular materials and interfaces.
  - Develop single molecules and/or nanoparticles that exhibit electronic functionality and measure their intrinsic electronic properties.

- Pathogen Countermeasures. ($ 5.189 Million)
  - Determine mechanisms of disease causing (virulence) factors in pathogens of concern to the DoD.

- Thermoelectric Materials. ($ 3.712 Million)
  - Develop thin film cooler utilizing quantum well structures.

- Fast Ship. ($ 0.888 Million)
  - Initiate a study to explore the underlying physics and the effects of material shaping on hydrodynamic drag reduction.

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(U) **FY 2000 Plans:**

- Portable Power. ($ 5.000 Million)
  - Design, build and test portable power systems that operate directly on logistics fuels.
  - Demonstrate an integrated 50W proton exchange membrane fuel cell operating on several novel hydrogen sources.
  - Demonstrate a portable, packaged direct methanol fuel cell.

- Nanoscale/Biomolecular Materials. ($ 7.167 Million)
  - Explore novel processing schemes for the formation of nanoscale/biomolecular materials and interfaces.
  - Explore the capabilities of quasicrystals, carbon nanotubes and other nanostructured materials for enhancing structural and functional performance of defense systems.
  - Establish focused basic research initiatives in biomimetics and other bioengineering disciplines to foster creative interdisciplinary research in biology and engineering and to ensure this critical technical area is responsive to future defense needs.

- Molecular Electronics. ($ 7.000 Million)
  - Demonstrate that two interconnected molecules and/or nanoparticles show the anticipated functionality.
  - Demonstrate the ability to reversibly and repeatably transfer information from one molecule or nanoparticle to another.
  - Demonstrate that molecular and/or nanostructured materials can perform a storage function that can be driven from one state to another by an external signal.

- Fast Ship. ($ 3.000 Million)
  - Explore novel methods of drag reduction (i.e., the use of air injection).
  - Design and build a small scale, high-speed model for micro bubble air flow testing.

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(U) FY 2001 Plans:

- Nanoscale/Biomolecular Materials. ($ 6.953 Million)
  - Demonstrate enhanced performance from materials and processes incorporating nanostructured components.
  - Demonstrate the use of quantum chemistry for the theoretical design of new nanoscale/biomolecular materials and structures.
  - Continue interdisciplinary basic research initiatives in biomimetics/bioengineering and begin exploration of potential defense applications.

- Molecular Electronics. ($ 9.000 Million)
  - Demonstrate that molecules and/or nanoparticles can self-assemble into functional, regular patterns forming a molecular memory.
  - Demonstrate assembly architectures that enable interconnected molecules and/or nanostructures to function even though some of the molecular components are defective.

- Fast Ship. ($ 4.000 Million)
  - Perform design trade studies, test and evaluate drag reduction technologies using small scale models, estimate resulting performance and determine the scalability of model-based results to full-size vessels.

(U) Other Program Funding Summary Cost:

- Not Applicable.

(U) Schedule Profile:

- Not Applicable.